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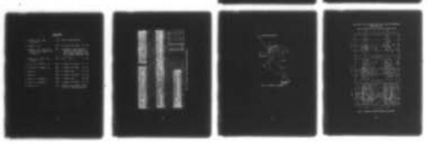

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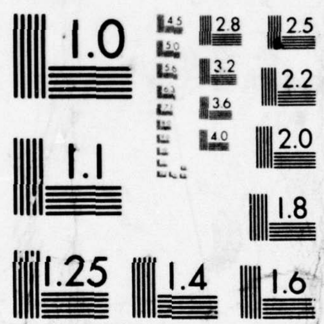

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On the Possibility that Sporadic E Ionization is a Source for Certain Scintillation Disturbances in the UHF Channels of FLEETSATCOM

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Space Environment Branch
Space Systems Division

October 1976

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Washington, D.C.

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The concept of wedge refraction is discussed and calculations of the amounts of refractive bending for possible models of sporadic E patches are presented. A general concept is developed but emphasis is placed upon possible effects at 250 MHz.

We conclude that for certain conditions, sporadic E patches may produce measureable fading effects observable at a ground terminal receiving UHF transmissions from a synchronous satellite. It is tentatively concluded that these phenomena will be most evident at mid-latitudes during

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20. Abstract (Continued)

summer daytime conditions. Single patches will produce quasi-periodic disturbances at each edge lasting the order of a minute, while, multiple patches will increase the disturbance duration. Noise-like disturbances will be produced for nonuniform wedges or wedge super-position.

Predictions of E_s scintillation effects on FLEETSATCOM are no better than the prediction of E_s patches which is obviously poor from a deterministic point of view. Only statistical information based upon archival data is available. Use of the vertical incidence ionosonde at Wallops Island, Virginia is suggested for extracting real-time assessment of the E_s scintillation possibility at NAVCOMSTA, Norfolk.

CONTENTS

ON THE POSSIBILITY THAT SPORADIC E IONIZATION IS A SOURCE FOR CERTAIN SCINTILLATION DISTURBANCES IN THE UHF CHANNELS OF FLEETSATCOM

INTRODUCTION

Recently a significant amount of amplitude fading of the UHF fleet broadcast channel of MARISAT/GAPFILLER was experienced at NAVCOMSTA, Norfolk [1]. In view of the fact that the events observed at Norfolk were unanticipated, since the UHF mid-latitude scintillation caused by F region irregularities is traditionally assumed to be negligible, it was decided to investigate the possibility of sporadic E as a source for scintillation disturbances. We find that sporadic E was indeed observed at Wallops Island, Virginia during the disturbance periods indicated above [1]. It is noteworthy, however, that sporadic E also occurred at times for which no scintillation was reported. In this memo we will argue that sporadic E may be a necessary condition for scintillation but it is not wholly sufficient.

Evidence for sporadic E scintillation effects was published by the author about a decade ago [Goodman, 2]. Figure 1 illustrates the type of disturbances observed at that time. From that study, it was found that scintillation depth in dB, was an increasing function of the probability that f_oE_s (the ordinary ray critical frequency) exceeds a given fixed value, say 5 MHz. Hence the strength of the disturbance is greatest for the most intense sporadic E patches. The study, based upon VHF transmissions (137 MHz) from the synchronous satellite Early Bird, did not suggest that the mere presence of sporadic E guaranteed scintillation effects. However, it did suggest, on the basis of considerable circumstantial evidence, that sporadic E is a necessary condition for scintillation if F-region irregularities are to be ignored.

The present memorandum report is an attempt to address the possibility that E_s patches generate scintillation effects on UHF transmissions.

Note: Manuscript submitted October 1, 1976.

GENERAL THEORY AND DISCUSSION

It is well known that transverse gradients in electron content (wedges of ionization) can produce radiowave bending or refraction. The amount of bending is given by

$$\epsilon(x) = \frac{K}{f^2}\frac{d}{dx}\int N(x,s)\,ds \qquad (1)$$

where s is measured along the direction of ray propagation,
x is transverse to the ray path,
f is the radio frequency (Hz)
and k = 40.5 with MKS units being employed.

Wedges of ionization at F region heights are well known to cause effects at HF in terms of angle-of-arrival fluctuations. These effects are limited due to the relatively small electron content gradients produced by travelling ionospheric disturbances [Goodman, 3].

The purpose of this memorandum is to examine the possible effects arising from electron content gradients at E region heights which might lead to the so-called E_s scintillation phenomenon. The main emphasis will be given to effects at 250 MHz because of the possibility that the Navy fleet satellite communication system (FLTSATCOM) may experience outages during the daytime at middle latitudes in a manner not currently indicated by existing scintillation codes. Existing codes describe F region effects primarily and indicate very little scintillation should be expected at 250 MHz except over the magnetic equator (for nocturnal equinox periods primarily) and for high latitudes (near the auroral oval). Nevertheless workers in the southern hemisphere (e.g., Bolton, Slee, and Stanley [4], Wild and Roberts [5], Ireland and Preddy [6],)and others in the Northern Hemisphere, (e.g., Dueno [7], Dagg, [8], Aarons, et al, [9] and Goodman, [2]) have observed scintillation effects which have been attributed at least circumstantially to sporadic E patches.

Since sporadic E patches are relatively thin (being a fraction of a kilometer to ■ 5 kilometers in thickness) extremely sharp gradients are required to produce interference fringes or fading effects at UHF. Assuming that the normal E region background is uniform and that sporadic E ionization represents an excess ionization, we may write:

$$\frac{d}{dx}\int N(x,s)\, ds = 1.24 \times 10^{10}\ t \sec\varphi\ (f_o^2 E_s - f_o^2 E)\ \frac{dg(x)}{dx} \tag{2}$$

where t is the slab thickness of the sporadic E patch,
φ is the local ray zenith angle,
f_oE_s is the ordinary ray critical frequency [MHz] for E_s ionization,
f_oE is the ordinary ray critical frequency [MHz] for the normal E region, and
g(x) is the excess ionization growth factor from the edge of the sporadic E patch to its center.

Figure 2 illustrates the geometry of the situation. Thus at 250 MHz

$$\frac{k}{f^2} = 6.48 \times 10^{-16}$$

and we have:

$$\varepsilon(x) = 8.04 \times 10^{-6}\ t\ \sec\varphi\ (f_o^2 E_s - f_o^2 E)\ \frac{dg(x)}{dx}. \tag{3}$$

It is important to realize that the bending introduced by wedge refraction is directed away from the gradient at both ends of the sporadic E patch. Thus we are concerned with a divergent lens mechanism. Therefore initial effects caused by patches (if they can be represented by wedges at their leading and trailing edges) precede the front edge transit time and are delayed from the trailing edge transit time. This ray divergence at the edge of the patches will cause interference with undisturbed rays and regular quasi-periodic fading will be the expected result.

For purposes of obtaining a benchmark let us compute the amount of refraction anticipated at 250 MHz for the following assumptions:

(i) Layer thickness $t = 2.5 \times 10^3$ meters
(ii) Zenith angle $\varphi = 45^\circ$
(iii) $f_o E = 5$ MHz
(iv) $f_o E_s = 15$ MHz
(v) $\frac{dq(x)}{dx} = 100\%$ per 10^3 meters (i.e., 10^{-3})

For this idealistic case $\epsilon \cong 5.67 \times 10^{-3}$ radians or $\cong 0.325$ degrees. If the height of the sporadic E patch is 100 kilometers (and the slant range = 140 kilometers for $\varphi = 45^\circ$) then the disturbance is $\cong$ 793 meters ahead of the patch on its leading edge and $\cong$ 793 meters behind the patch on its trailing edge. Since a typical sporadic E drift velocity is 100km/hour, the observed disturbance would last about 30 seconds at each edge of the patch. These disturbances would be quasi-periodic.

To yield interference effects it is clear that the following condition must be fullfilled:

$$\Delta R = R\,(\sec \epsilon - 1) \geq \frac{\lambda}{2} \tag{4}$$

where ΔR is the path length difference between the direct and refracted (bent) ray, R is the slant range to the E_s path, ϵ is the refractive angle, and λ is the radio wavelength.

From the relation $\lambda f = 3 \times 10^8$ and the encorporation of equation 3 we have:

$$\Delta R = R\left\{\sec\left[8.04 \times 10^{-8}\, t \sec\varphi\left(f_o^2 E_s - f_o^2 E\right)\frac{dq}{dx}(x)\right]-1\right\} \geq 0.6. \tag{5}$$

For small ϵ

$$\sec \epsilon = 1 + \tfrac{1}{2}\sin^2 \epsilon = 1 + \frac{\epsilon^2}{2}$$

and equation (5) reduces to

$$\Delta R = \frac{R}{2}\,\epsilon^2 \geq 0.6, \tag{6}$$

or to a good approximation

$$\Delta R = 3.23 \times 10^{-11}\ ht^2 \sec^3 \varphi\ (f_o^2 E_s - f_o^2 E)^2 \left(\frac{dq(x)}{dx}\right)^2 \geq 0.6$$

where $R = h \sec \varphi$ with h being the height of the E_s patch.

For the same properties of the sporadic E patch imposed in the earlier example, we have:

$$\Delta R = 2.28 \geq 0.6.$$

Thus inequality (6) is satisfied for the rather strong conditions imposed. The condition which must be relaxed somewhat is the stipulation of

$$(f_o E_s^2 - f_o E^2)$$

being 200 MHz^2 since scintillation has been associated with sporadic E such that

$$f_o E_s \geq 4 \text{ MHz}$$

for a transmission frequency of 137 MHz [Goodman, 2] [Gupta and Kersley, 10].

> [For 137 MHz, ΔR must be greater than 1.1 meters which is a factor of 1.82 more than the requirement at 250 MHz but the refraction effect at 137 MHz (proportional to f^{-2}) is more by a factor of 3.33. Hence the disturbance "probability" under the same conditions at 250 MHz is 55% of the 137 MHz disturbance "probability". If we requre
>
> $$f_o E_s \geq 5 \text{ MHz}$$
>
> for UHF rather than 4 MHz for VHF then we essentially provide identical conditions. However, this is an heuristic argument and not rigorously reasoned].

If we relax the constraints on

$$(f_o E_s^2 - f_o E^2)$$

We must require that

$$\frac{dq(x)}{dx}$$

be larger (say the order of 10^{-2} rather than 10^{-3}) or that the vertical structure be considerably more complicated. There is some evidence that both of these revisions are plausible.

Gupta and Kersley [10] have shown that VHF scintillation (137 MHz) from synchronous satellites observed at northern midlatitudes during summer daytime conditions is associated with sporadic E. This corroborates the earlier work of Goodman [2] and others cited above. Their new result, however, in addition to the fact that

$$f_o E_s \geq 4 \text{ MHz}$$

is a necessary condition for scintillation, is that a vertical or diffuse structure is also important. The association between sporadic E and scintillation was 90% when

$$f_o E_s \geq 4 \text{ MHz}$$

and when the disturbances lasted more than 15 minutes. Also 50% of the disturbances either originated or terminated with a "ringing-type" irregularity. That is, it was quasi-periodic. Under quiet conditions they found that for disturbances which lasted at least 15 minutes, 70% were associated with range spreading of E_s ionization.

To summarize, we anticipate that FLEETSATCOM may experience midday and midlatitude scintillation effects at 250 MHz provided sporadic E is present in the vicinity of the ray linking the earth terminal to the geostationary satellite. The simple theory requires strong sporadic E in conjunction with relatively gently gradients or moderate sporadic E in conjunction with sharp gradients and/or considerable vertical structure. The situation which favors the observation of E_s scintillation outages at 250 MHz and at midlatitudes is a moderately low elevation path between the satellite and ground station during summer daytime conditions.

Figure 3 shows how sporadic E varies with month and local time for the Washington area [12]. Maps such as these may be useful in estimating the total number of possible E_s scintillation events for FLTSATCOM at Norfolk, but there would be little utility in doing this except for crude planning purposes. The most rewarding possi-

bility would be to access data from the Wallops Island ionosonde in real time for purposes of short-term assessment and hindcasting of system failure.

FUTURE PLANS

The Space Environment Branch (Code 7950) of NRL is developing a capability to forecast average scintillation characteristics on a global scale using existing codes. These essentially F-region codes are being up-dated to indicate "alerts" for E_s-related events but this feature will not be qualitatively accurate.

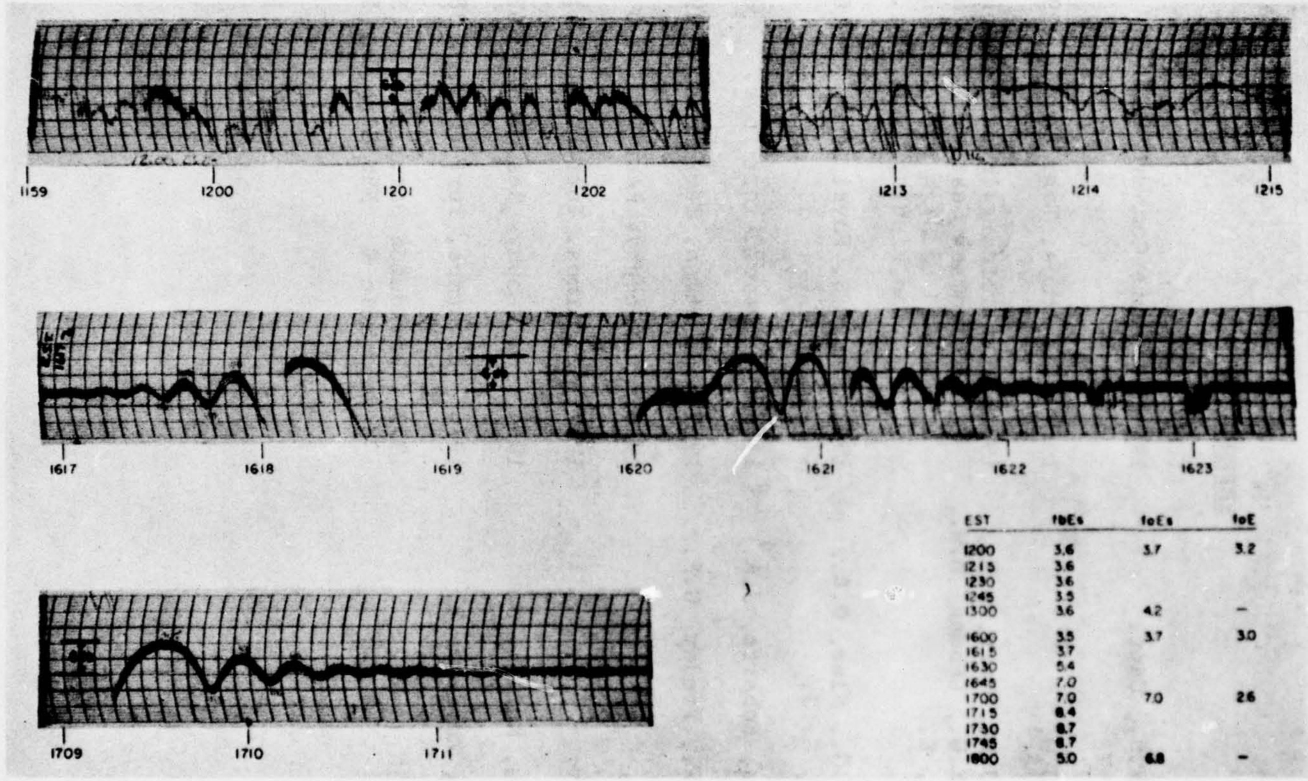
The RED-ANT program being initiated at NRL is designed to examine the improvement made in forecasting ionospheric effects if the data base is augmented by environmental data obtained in real-time. This requires a global network of remote sensors and connectivity between these sensors and a central processing computer for event monitoring and short-term forecasting.

Research currently envisioned includesmonitoring of Wallops Ionosonde data and comparison with FLTSATCOM outages or fading events. This will enable our forecasting precedures to be made more precise for the Norfolk NAVCOMSTA.

As part of a general Environmental Assessment program to be initiated in FY77,it is our intention to develop a full data base using SOLRAD HI and other sensors the output of which is contained at either AFGWC, the SELDADS system at NOAA or the SEDAC facility at NRL. This data base will be exploited for the purpose of extracting information concerning magnetic storms, scintillation phenomena, and other events of importance to DoD systems performance.

REFERENCES

1. Enright, R.E., Capt. U.S. Navy	1967	Private Communication	
2. Goodman, J.M.	1967	J. Atmos. Terr Phys.	29, 607
3. Goodman, J.M., Gott, E.L., Morin, K.W., Lehman, M.W., Piernik, E.	1972	Preliminary Investigation of Thomson Scatter Radar as an Aid to High Frequency Direction Finding" NRL Rpt. 7385	
4. Bolton, J.G., Slee, O.B., Stanley, G. J.	1953	Aust J. Phys.	6, 434
5. Wild, J.P., Roberts, J.A.	1956	J. Atmos. Terr Phys.	8, 55
6. Ireland, W., Preddy, G.F.	1967	J. Atmos. Terr Phys.	29, 137
7. Dueno, B.,	1956	J. Geophys Res.	61, 535
8. Dagg, M.	1957	J. Atmos. Terr Phys.	11, 118
9. Aarons, J., Mullen, J.	1964	J. Geophys Res.	69,1785
10. Gupta, A., Kersley, L.	1976	J. Atmos. Terr Phys.	38, 615
11. Smith, E. K.	1957	Worldwide Occurrence of Sporadic E NBS Circular 582	



EST	fbEs	foEs	foE
1200	3.6	3.7	3.2
1215	3.6		
1230	3.6		
1245	3.5		
1300	3.6	4.2	–
1600	3.5	3.7	3.0
1615	3.7		
1630	5.4		
1645	7.0		
1700	7.0	7.0	2.6
1715	8.4		
1730	8.7		
1745	8.7		
1800	5.0	6.8	–

Fig. 1 — Records of noisy and quasi-periodic scintillation

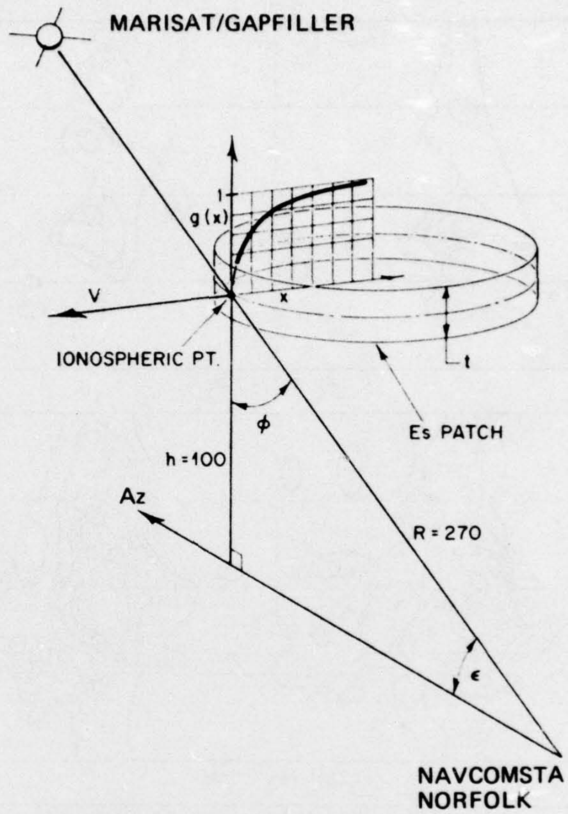


Fig. 2 — Geometry of situation

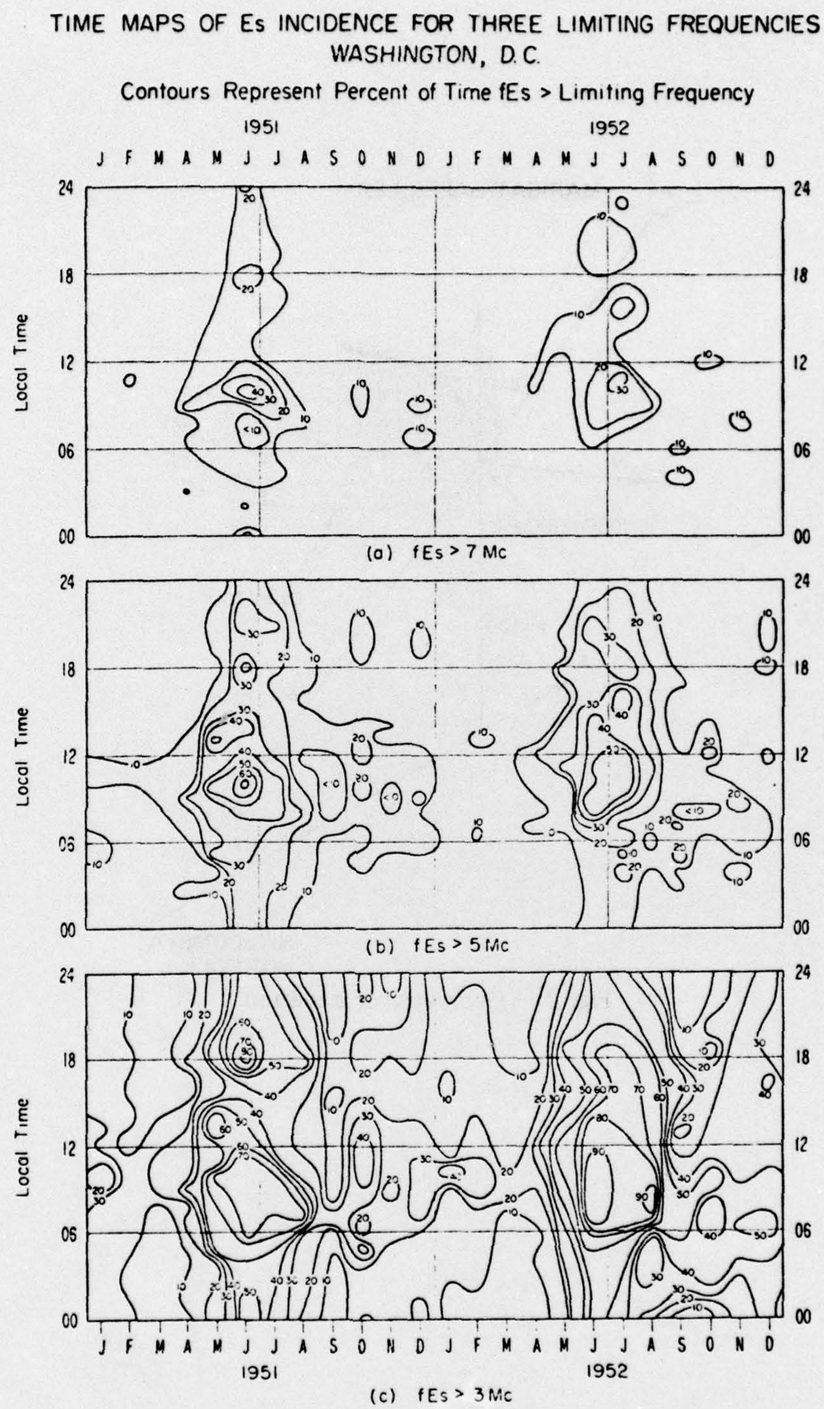


Fig. 3 — Sporadic E data (from NBS circular 582)